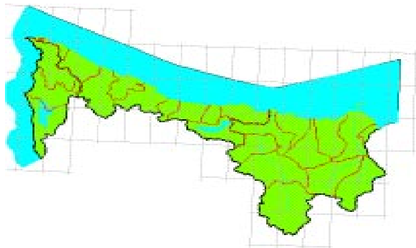

Dungeness River Basin Pilot Assessment

Elwha-Dungeness Basin (WRIA 18)

Geographic Description

The Elwha-Dungeness Basin (WRIA 18) is located in the northeastern section of the Olympic Peninsula. The entire basin covers an area of approximately 580 mi^2. The Elwha and Dungeness Rivers are the principal drainages in the basin covering 320 mi^2 and 200 mi^2 respectively. Within the Elwha-Dungeness basin there are eleven tributaries flowing directly into the Strait of Juan de Fuca independent of the Elwha and Dungeness Rivers. There are eleven Washington State Watershed Administrative Units (WAUs) in the Elwha-Dungeness Basin (Table 1).

Salmon and Steelhead Stocks

Recent studies of salmon populations in the Pacific northwest have reached similar conclusions regarding the status of salmon and steelhead in the Elwha-Dungeness basin. The Salmon and Steelhead Stock Inventory (SASSI, WDF et al. 1993) identified fifteen distinct salmon and steelhead stocks within the Elwha-Dungeness basin and assessed the fitness of each based on recent trends in adult escapement (Table 2). Three of the state's twelve critical stocks, as determined in SASSI, spawn and rear in the Elwha-Dungeness basin. Eight stocks were determined to be depressed and just two healthy. The status of two stocks was not determined (WDF et al. 1993). Subsequent studies have found no healthy salmon or steelhead stocks in the Elwha-Dungeness (McHenry et al. 1996, Huntington et al. 1994).

In addition, McHenry et al. (1996), identified 12 salmon populations believed to be extirpated from

Table 1. Washington State Watershed Administrative Units (WAUs) located in Elwha-Dungness basin, WRIA 18.

WAU Number	Name	Drainage
180103	Dungeness Valley	Dungeness River
180104	Bell Creek	Independent
180105	Gray Wolf	Dungeness River
180106	Upper Dungeness	Dungeness River
180201	Morse Creek	Independent
180202	Siebert-McDonald	Independent
180211	Port Angeles	Independent
180307	Mount Wilder	Elwha River
180308	Mount Carrie	Elwha River
180309	Mount Mills	Elwha River
180310	Sutherland-Aldwell	Elwha River

Table 2. Summary of WRIA 18 (Elwha - Dungeness) SASSI stocks and their status

SASSI Stock	Origin	Production Type	Status
Dungeness Spring/Summer Chinook	Native	Wild	Critical
Elwha/Morse Creek Summer/Fall Chinook	Native	Composite	Healthy
Dungeness/East Strait Tribs Chum	Native	Wild	Unknown
Elwha Fall Chum	Native	Wild	Unknown
Dungeness Coho	Mixed	Composite	Depressed
Morse Creek Coho	Mixed	Wild	Depressed
Elwha Coho	Mixed	Composite	Healthy
Upper Dungeness Pink	Native	Wild	Depressed
Lower Dungeness Pink	Native	Wild	Critical
Elwha Pink	Native	Wild	Critical
Dungeness Summer Steelhead	Unresolved	Unresolved	Depressed
Elwha Summer Steelhead	Unresolved	Unresolved	Depressed
Dungeness Winter Steelhead	Native	Wild	Depressed
Morse Creek/Independents Winter Steelhead	Unresolved	Unresolved	Depressed
Elwha Winter Steelhead	Mixed	Wild	Depressed

the Elwha-Dungeness Basin: Elwha pink, sockeye, and spring chinook; Morse Creek spring chinook; Peabody Creek coho and chum; Tumwater Creek coho and chum; Valley Creek coho and chum; McDonald Creek chum; and Siebert Creek chum.

Geology

Bedrock formations

The geology of the Strait of Juan de Fuca area, like most of western Washington, is dominated by the influences of mountain building and glaciation. Olympic peninsula bedrock is characterized by two major rock groups, core rocks and peripheral rocks. The core rocks are located in the center and western sections of the peninsula and are made up mostly of highly deformed, and in eastern sections, partially metamorphosed sedimentary rocks. The peripheral rocks are composed of folded, but much less deformed, unmetamorphosed sedimentary rocks overlaying a thick deposit of volcanic basalt. The basalt deposits have been tipped on edge and folded into a formation resembling a horseshoe, encircling the mountainous core rocks, paralleling the Strait of Juan de Fuca, and opening to the Pacific Ocean. Named for the bay west of Port Angeles, this basaltic horseshoe is known as the Crescent Formation. Basaltic rocks of the Crescent Formation date to the early Eocene, whereas core sedimentary rocks have been dated to as late as the early Miocene.

Building of this general configuration began during the early Miocene epoch when ocean sedimentary rock, riding eastward on the oceanic plate was thrust beneath an older, denser, and harder deposit of volcanic basalt, itself overlain with sedimentary rock. As the eastward moving sedimentary rocks were forced between the subducting oceanic plate and the basalt, the later was tilted up on its western side. Finally, the subduction zone of the oceanic plate moved west, and the less dense sedimentary core rocks rose forming the high center of the Olympic Mountains (Tabor 1987).

Surficial geology

Cordilleran ice reached the northern Olympic Peninsula as many as six times during the Pleistocene epoch ending some 10,000 years ago. It was during these episodes that most of the unconsolidated sediments found in the

Elwha-Dungeness Basin were deposited. Unconsolidated sediments directly associated with Pleistocene glaciation include: outwash silts, sands, and gravels from advancing and regressing glaciers; unsorted lodgement and partially sorted ablation tills; and fine silts and clays deposited in glacial lake bottoms. Streams and overland flow have reworked both bedrock and glacial sediments forming alluvial plains, fans, and deltas.

Holocene

By thirteen thousand years ago, the cordilleran ice mass had melted back to north of the Puget Sound area (Thorson 1979). The newly exposed landscape was prone to erosion and streams carried a large load of sediments. As a cooler and wetter climate developed regionally between nine thousand and six thousand years ago, conifer dominated forests became established, sediment yields declined, and stream channels stabilized, improving conditions for salmonid production (Benda 1992).

Stream network

Major drainage systems of the Olympic Peninsula radiate like the spokes of a wheel from the high center of the Olympic Mountains. Both the Elwha and Dungeness Rivers originate in alpine glaciers located high in the mountains of the relatively soft core rocks and flow north, cutting through the harder basaltic periphery. Aided by the work of past continental and alpine glaciers, sub-watershed channels of the Elwha and Dungeness have cut deep into the core rocks, especially along faults that are generally concentric to the Crescent Formation. Independent drainages in the Elwha-Dungeness Basin, including McDonald (23.0 mi^2), Siebert (19.5 mi^2), Bagley (7.71 mi^2), and Ennis (8.7 mi^2) Creeks, originate north of the low ridge of the Crescent Formation. Morse Creek (46.6 mi^2), located midway between the Elwha and Dungeness Rivers is the largest of independent drainages in the Elwha-Dungeness Basin. Like the Elwha and Dungeness Rivers, Morse Creek originates south of the Crescent Formation, within the core Olympic Mountains.

Climate

The climate of the Strait of Juan de Fuca is mild, reflecting the influence of moist air from the Pacific Ocean. Average summer low and high temperatures range between 50 and 72 degrees F. Winter temperatures in the lower elevations are moderated by prevailing winds which blow from the Pacific Ocean eastward through the Strait of Juan de Fuca (Puget Sound Cooperative River Basin Team [PSCRBT] 1991).

The orographic effect of the Olympic Mountains on weather systems from the Pacific Ocean is responsible for a dramatic precipitation gradient between the high elevations of the upper watershed areas of the Elwha and Dungeness and the leeward areas of the Olympic peninsula. Moist Pacific air masses are forced up the windward side of the high Olympic Mountains and, as they cool, vapor pressure reaches saturation, causing increasingly heavy precipitation with altitude. On the leeward side of the Olympic mountains, air masses are warmed and dried to unsaturated vapor pressure as they lose elevation. Average annual precipitation ranges from over 100 inches in the headwaters of the Elwha to under 20 inches in the rainshadow of the Olympics near Sequim.

Hydrology

Watersheds of the Elwha and Dungeness Rivers, and Morse Creek all accumulate significant snowpack in winter, whereas the remaining independent streams are rain dominated. This has important hydrological implications (Figure 1). Base flows in the larger watersheds, Morse Creek and Dungeness River, are largely maintained by melting snowpack, whereas low flow conditions arrive earlier, and persist for a longer period in the smaller independent streams such as Siebert Creek. The hydrologic regime is biologically important as well. The Elwha and Dungeness Rivers, and Morse Creek have flows characteristic of watersheds having significant snow and transient snow zones. These watersheds support a greater number of anadromous salmon species than

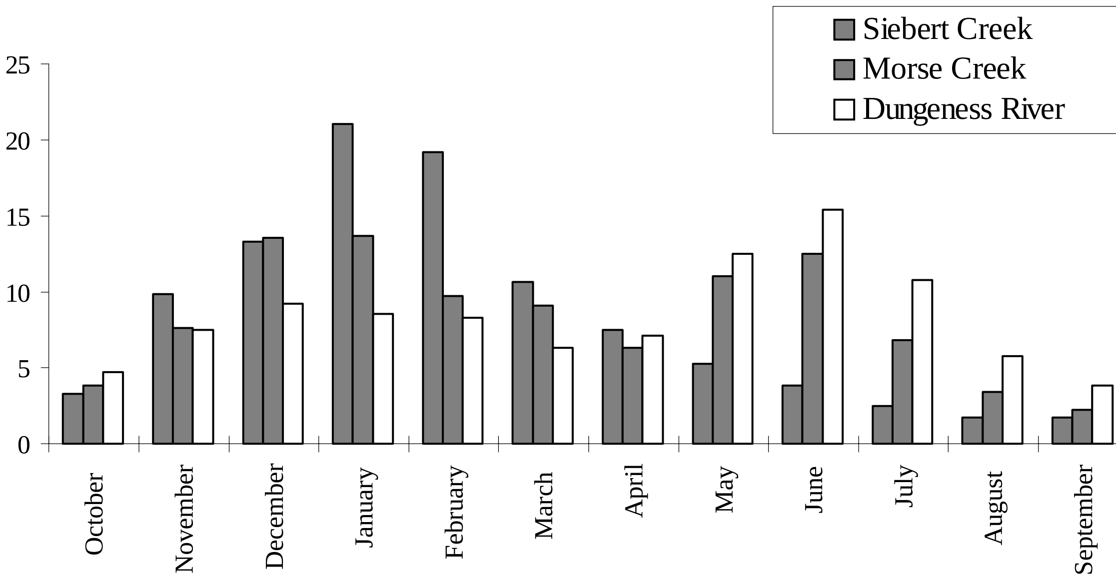

Figure 1. Mean Monthly flow as a percentage of long term mean annual flow - Siebert Creek, Morse Creek, and Dungeness River.

the smaller, rain and rain-on-snow dominated systems, such as Siebert and McDonald Creeks.

Land Use

The major population centers in the Elwha-Dungeness are the cities of Port Angeles, population 18,540, and Sequim, population 4,200 (Washington State Office of Financial Management, 1995). The populated portion the basin lies completely within Clallam County. The southern portion of the basin crosses into Jefferson County, but this area is largely within Olympic National Park.

Land use in the basin is diverse. Logging, agriculture, urban, and industrial land uses are all present and have influenced the quality and quantity of salmon and steelhead habitats. Large areas of the upper Elwha - Dungeness Basin are used for public and private timber production. Urban effects are most acute in the Port Angeles area where they so severely impact streams that some salmon populations have been completely eliminated (McHenry et al. 1996). Historical estuarine habitat was destroyed during industrial port development in Port Angeles Harbor. Agriculture, rural, and suburban residential development have led to a variety of riparian and in-channel impacts on salmon habitat including removal of riparian vegetation, bank armoring, diking, ditching, gravel and wood removal, and excessive water withdrawals. Finally, hydroelectric dams have blocked all but about five miles of anadromous habitats of the Elwha River, most of which remain in pristine condition within the boundaries of Olympic National Park.

As a general indicator of intensity of land use activities, road densities for watershed administrative units within the Elwha-Dungeness Basin are given in Table 3. Densities range from 0.0 mi/mi^2 in roadless Mount Wilder, to 5.96 mi/mi^2 in heavily developed Bell Creek. Road densities exceeding 2.5 mi/mi^2 are considered high on federal forests, however, road densities exeeding 3 mi/mi^2 are common in urban and suburban environments of the Elwha-Dungeness Basin (USDA 1995).

Watershed Description

Dungeness River Watershed

The Dungeness River is located on the East side of the Elwha - Dungeness Basin and covers an area of approximately 200 mi^2. The mouth of the Dungeness River opens to Dungeness Bay, the largest nearshore estuary in the Strait of Juan de Fuca.

Geographic Description

Several small tributaries come together at about 4000 feet above mean sea level to form the Dungeness River. Small tributaries extend up beyond 6000 feet. From about rivermile 30, the mainstem river drops through steep gradients as it flows northward toward the Strait, finally moderating at about rivermile 10 in the foothills. The channel is largely braided between rivermile 4 and rivermile 8. An alluvial fan has formed in the lower river north of Happy Valley as the position of the channel has gradually moved from east to west since the last glacier melted away at the end of the Pleistocene.

There are 50 tributaries to the mainstem Dungeness, the most important of which is the Gray Wolf River. The Gray Wolf River joins the mainstem Dungeness from the southwest at approximately rivermile 16. The Gray Wolf has two major tributary streams: Grand Creek and Cameron Creek. Summer flows from Cameron Creek are fed by small alpine glaciers located in Cameron basin in the southwestern corner of the Dungeness watershed. Williams (WDF 1975) estimated the total length of the mainstem Dungeness at 31.9 miles and the total length of the Gray Wolf at 17.4 miles. Total length of tributaries to the Dungeness, excluding the Gray Wolf River, were estimated at 162 miles, including 49 miles of irrigation ditches and canals. The Gray Wolf River was estimated to have 94 miles of tributaries.

Geology

The geology of the Dungeness River watershed is similar to that described above for the Elwha-Dungeness. Glaciolacustrine deposits on steep hillslopes of headwater basins such as the upper Dungeness River, Gold Creek, and Silver Creek are particularly sensitive to management activities with a higher than normal mass wasting potential. Orsborn and Ralph (1994), for example, attributed elevated sediment bedloads in the lower mainstem Dungeness to large slope failures in the Gold Creek watershed accompanied by dramatic increases in road densities during the 1960s, 1970s and early 1980s.

Surface Hydrology

The lowland areas of the Dungeness River watershed are in the rainshadow of the Olympic Mountains. Flows are maintained by melting snow and precipitation in the upper watershed. Spring melt of the snowpack has a significant influence on the annual hydrograph. The United States Geological Service (USGS) maintains a streamflow gaging station (No. 12048000) at rivermile 11.8. The period of record for this gage is 1924-30 and 1938-present. Average monthly high, mean, and low flows were developed from the USGS gage data (Figure 2). Peak high, mean, and low flows occur in May and June. A second peak in average high and mean flows occurs during the winter months reflecting the extreme discharge response to rain and rain on snow events. Minimum seven day low flows typically occur between mid-September and mid November (Orsborn and Ralph 1994).

Irrigation

Surface waters are withdrawn from the Dungeness at several locations downstream of the USGS gage station (RM 11.8) to supply a network of over 400 miles of irrigation ditches used by farmers in the lower watershed (PSCRBT 1991). There are six diversions on the lower Dungeness River serving nine irrigation districts or companies. Irrigation districts have combined adjudicated rights to draw 576 cubic feet per second from the Dungeness River, more than the average mean monthly flow for every month except May and June, and more than the average minimum monthly flow of every month of the year (Figure 2).

Water Quality

Water quality of the Dungeness River and its tributaries is generally high (PSCRBT). Most pollution originates as run-off from agricultural and residential areas. There are several small tributaries

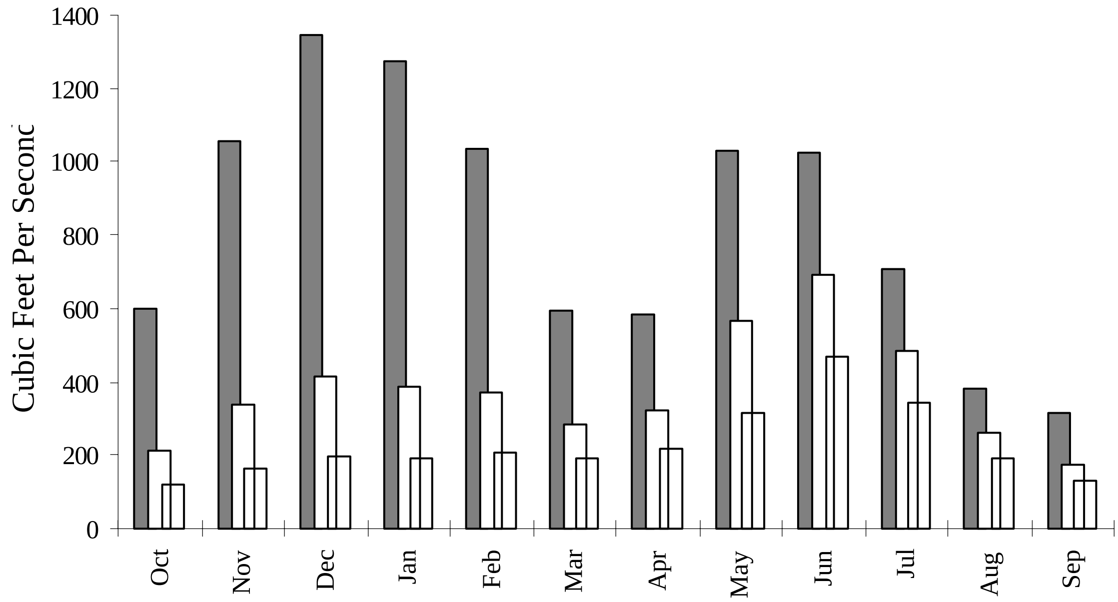

Figure 2. Dungeness River - Average Maximum, Mean and Minimum Monthly Flows (1923-1930; 1937-1994)

and irrigation ditches contributing surface water to the Dungeness River that do not comply with the state's clean water standards (Puget Sound Cooperative River Basin Team [PSCRBT], 1991). Matriotti Creek, a small tributary in the lower Dungeness watershed, is currently classified as an impaired water body (fecal coliform) by Washington State. Agriculture is the dominant land use in the Matriotti Creek sub-watershed.

Maximum temperatures in the lowest portion Dungeness River mainstem (RM 1 to RM 13) exceed the preferred range for chinook and pink spawning (Figure 3). Compared with the upper river, the surface of the lower river receives much less shade protection from riparian vegetation and steep valleys resulting in higher peak temperatures. Streambed aggradation and irrigation withdrawals probably contribute to the elevated temperature regime in the lower river (Orsborn and Ralph 1994).

Groundwater

The surface of the lower Dungeness Watershed lies immediately above a broad unconfined, shallow (watertable) aquifer. There is a high degree of hydraulic continuity between surface waters of the lower Dungeness watershed, including streams, ponds, lakes and wetlands, and the shallow aquifer (PSCRBT 1991, JTS'KT 1994, Clallam County, 1995). Groundwater is recharged from precipitation, the Dungeness River, and infiltration from irrigation ditches that draw from the Dungeness River. Because of the scarcity of rainfall in the lower watershed, recharge from surface waters (streams, irrigation ditches, etc.) far exceeds that of precipitation (PSCRBT 1991). As much as forty percent of the recharge water is delivered from the irrigation system (JTS'KT 1994). A USGS study suggested that if the irrigation system were terminated, the groundwater level in the watertable aquifer would decline as much as twenty feet on average and that several hundred of the 1100 wells identified at the time could go dry (Drost 1983). Irrigators drawing from the Dungeness River are currently delivering the greatest share of water consumed through domestic wells.

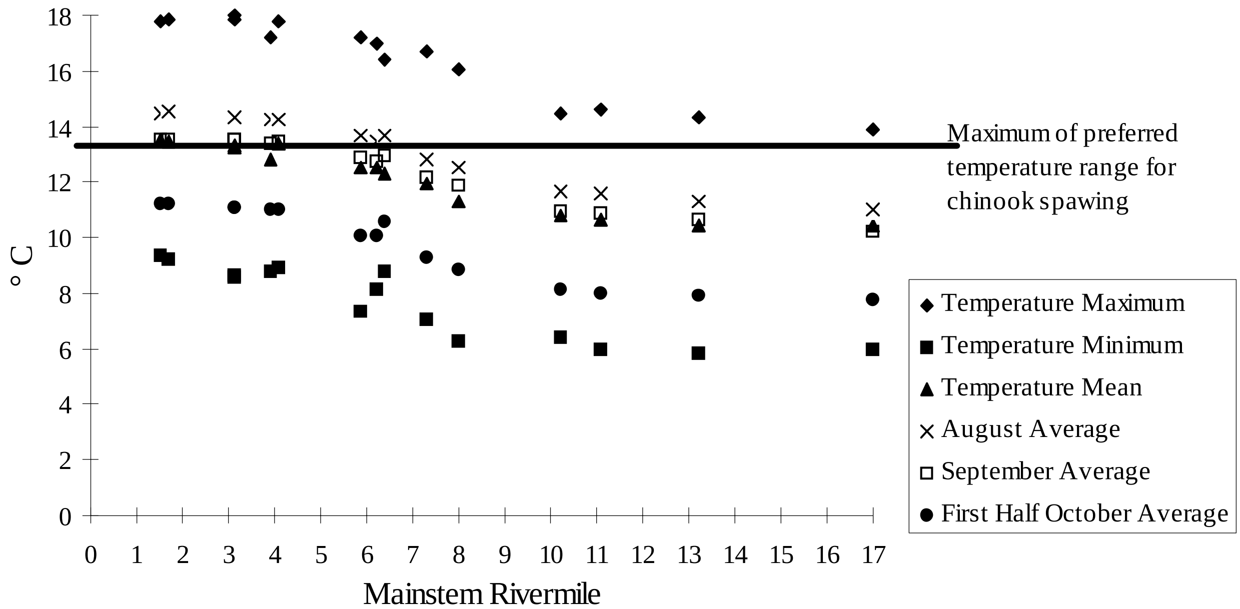

Figure 3. Water temperature data, August - October, by mainstem Dungeness rivermile (source: Orsborne and Ralph 1994)

The shallowness of the aquifer and the high permeability of many of the soils in the area have led to some concern for the quality of groundwater which is used for, among other things, residential consumption. Recent studies have documented an increasing trend in nitrate levels of water drawn from wells distributed about the Sequim-Dungeness area. (PSCRBT 1991, JTS'KT 1994). There are 3000-4000 wells in the watershed, 86% of which are for domestic use. The ground watertable is usually less than 50 feet from the surface so that most wells are less than 100 feet deep (PSCRBT 1991).

Land cover and land use

Land use

Land uses have been delineated for the Dungeness River area watershed covering the Dungeness River, Siebert and McDonald Creeks, and independent tributaries east to Port Williams north of Sequim Bay (PSCRBT 1991). Although the area extends beyond the boundaries of the Dungeness watershed, land uses in the larger area are generally reflective of trends within the Dungeness. Major land uses are commercial forestry (43%) concentrated in the upper elevations of the watershed, Olympic National Park land (30%) covering the southwest portion of the watershed, and rural/agriculture (21%) concentrated in the lower watershed (PSCRBT 1991).

Vegetation

Most of the Dungeness watershed is classified in the Western Hemlock vegetation zone (Henderson et al 1989). Douglas fir tends to be the dominant tree species due to the history of frequent, wide-spread, sometimes intense fires. Large, stand replacement fires are believed to have occurred in 1308, 1508, and 1701. The size and recurrent nature of these fires resulted in large even-aged tracts of forest, except in less affected riparian and higher elevation areas. Wildfires associated with land clearing were common during the settlement period from 1860 to the early 1900s. More recently, public and private forests managed for timber production have been converted to even aged, monotypic stands of Douglas fir (Vos 1995).

Fire was likely used by Native Americans in the lower watershed to maintain savanna and prairie communities that attracted grazing animals, and that promoted the spread of edible plants such as camas. These areas were occupied by Euro-American settlers in the mid-19th century and transformed by agricultural, residential, and commercial development (Vos 1995).

A significant portion (25,000 acres, 14%) of the watershed is classed in the Non-Forest Zone, defined as areas naturally unsuitable for forest vegetation because of elevation, soils limitations, or other site specific conditions (Vos 1995). Except for alder- and cottonwood-dominated riparian areas, much of the lower Dungeness Watershed is now non-forested, having been converted to cropland and pasture in the late 19th and early 20th centuries (USDA 1995, PSCRBT 1991).

Roads

Road densities vary significantly by sub-watershed from very high densities (4.61 mi/mi^2) in the lower, more developed area of the watershed to very low (0.17 mi/mi^2) within Olympic National Park (Table 3). Roads and associated timber harvest activities in recent decades on the Olympic National Forest are suspected by some to have contributed to dramatic increases in bedload sediments delivered to and deposited in the lower Dungeness River channel Lichatowich 1993a, Orsborn and Ralph 1994). Slope failures are especially evident in Gold Creek, a sub-watershed with a high road density (3.0 miles/mile^2) where inherently unstable glaciolacustrine deposits are a dominant geologic feature. Eddie Creek, adjacent to Gold Creek and also containing significant glaciolacustrine deposits, has a road density of 4.2 miles/mile^2. Road densities for both Eddie Creek and Gold Creek exceed the U. S. Forest Service threshold value of 2.5 miles/mile^2 for measuring the impact of roads on basins (USDA 1995).

Riparian vegetation

Condition of riparian vegetation varies greatly in the Dungeness watershed. Land survey maps from the early 20th century indicate that when vast sections of the lower watershed were converted to crop and pasture land, riparian areas were cleared of trees. Many riparian areas in the lower watershed remain in a deforested condition or are dominated by deciduous species such as red alder and black cottonwood. Riparian forests in Olympic National Park, including most of the Gray Wolf River and its tributaries, are in an essentially unmanaged condition.

The Dungeness Watershed Analysis assessed riparian condition based on large woody debris and shade

Table 3. Road densities by Washington State Watershed Administrative Unit (WAUs) in the Elwha-Dungeness basin, WRIA, 18.

WAU Number	Name	Drainage	Road Density (mi/mi^2)
180103	Dungeness Valley	Dungeness River	4.61
180104	Bell Creek	Independent	5.96
180105	Gray Wolf	Dungeness River	0.17
180106	Upper Dungeness	Dungeness River	0.96
180201	Morse Creek	Independent	0.96
180202	Siebert-McDonald	Independent	2.87
180211	Port Angeles	Independent	3.12
180307	Mount Wilder	Elwha River	0
180308	Mount Carrie	Elwha River	0.04
180309	Mount Mills	Elwha River	0.5
180310	Sutherland-Aldwell	Elwha River	2.26

Table 4. Estimated large woody debris recruitment potential for the Dungeness River and it's tributaries, (USDA 1995; WA Forest Practices Board, 1995).

Stream	Good %	Fair %	Poor %
Cameron Creek (to 3500 ft)	94	0	6
Canyon Creek	81	9	10
Lower Dungeness River	2	53	45
Middle Dungeness River	79	2	19
Upper Dungeness River	91	3	6
Gold Creek	51	10	39
Grand Creek (to 4000 ft)	99	1	0
Gray Wolf River (to 3000 ft)	86	0	14
Mattriotti Creek	2	25	73

Good: Areas have existing large wood in riparian zone in coniferous growing trees.
Fair: Areas have large deciduous trees or dense young conifer trees, i.e.,k potential to produce large coniferous trees in the future.
Poor: Areas have no large standing wood or sparse large deciduous trees or sparse young conifers or young deciduous stands.

functions (USDA 1995). Riparian functions were found to be most degraded in the lower watershed (Tables 4 and 5). The results for Matriotti Creek, with most of its stream length rating poor for both shade and large woody debris recruitment, are probably indicative of general conditions for tributaries, side channels, and ditches that join the mainstem downstream of rivermile 10, where agriculture and residential land uses are concentrated. On the mainstem, peak temperatures increase dramatically downstream of rivermile 10, indicating a loss of shade (see section 2.3.1 water quality) . Riparian areas on diked reaches of the lower Dungeness River mainstem are essentially non-functional. Riparian forests with significant conifer components were found on streams within the boundaries of Olympic National Park (Cameron Creek, Grand Creek, Gray Wolf River, and Upper Dungeness River).

Habitat Assessment

Results: watershed level

The quantity (by length) and types of salmon and steelhead habitats in the Dungeness River watershed are summarized in Table 6. Low

Table 5. Estimated percent shade cover of the Dungeness River and tributaries.

	Percent of Stream Length				
Percent Shade	**0 - 20**	**20 - 40**	**40 - 70**	**70 - 90**	**90 - 100**
Cameron Creek	0	0	4	0	96
Canyon Creek	0	0	0	7	83
Lower Dungeness River	61	35	4	0	0
Middle Dungeness River	0	0	75	25	0
Upper Dungeness River	0	0	9	9	82
Gold Creek	5	13	7	34	41
Grand Creek	0	0	0	0	100
Gray Wolf River	13	4	20	37	26
Mattriotti Creek	51	19	0	0	30

Table 6. Summary of habitats found in Dungeness River watershed.

Habitat Type	Gradient Class	Length (mi.)	%
Large Tributary	<= 1%	5.8	15
	1-2%	12.5	32
	2-4%	16.8	42
	4-8%	4.4	11
	>8%	0	0
	Total	39.5	100
Small Tributary	<= 1%	17.6	40
	1-2%	1	2
	2-4%	7.9	18
	4-8%	8.9	20
	>8%	9	20
	Total	44.4	100
Side Channel		3.3	

gradient habitat (both large and small tributary) is concentrated in the lower Dungeness watershed. The anadromous reaches of the Gray Wolf River are steeper in gradient, being mostly between 2% and 8%. All side channels identified are located on the lower mainstem Dungeness.

The lengths of three habitat types are shown graphically in Figure 4: large tributaries (width greater than or equal to 6m) which total 39.5 miles, small tributary (width less than 6m) which total 44.4 miles, and side channels witch total 3.3 miles. Quantities shown estimate the full extent of historically accessible anadromous (all species) habitat. Positive quantities represent unobstructed habitats, negative quantities indicate habitat partially, totally, or potentially obstructed by existing anthropogenic structures: culverts and dikes.

Obstructed Habitat - Small Tributaries

The current status of individual culverts (there were 127 total in the Dungeness River watershed) identified in this analysis is generally not known, instead, it is assumed that culverts within anadromous range are potentially obstructing habitat. Based on the length of small tributaries identified, 51 percent of existing small tributary habitats are potentially obstructed by culverts.

Obstructed Habitat - Side Channels

There were two notable areas of side channel obstruction on the lower mainstem identified in this analysis. The first is a large oxbow side channel that occurs between river mile 2 and river mile 3 that has been completely blocked by a U.S. Army Corps of Engineers dike. The second obstructed side channel occurs upstream of U.S. Highway 101 near a residential development at Dungeness Meadows. Extension of the Dungeness Meadows dike to protect private property has in recent years blocked upstream access to this large, slough-like side channel. Flow in the side channel is maintained through subsurface hydraulic continuity with the mainstem. Based on the length of side channels identified in this analysis, 31 percent of existing side channels are at least partially obstructed by dikes.

Due to the amount of agricultural and residential development activity in the Dungeness floodplain in proximity to the present location of the mainstem channel, it is likely that this analysis underestimates the quantity of historically available side channel habitat.

Habitat Hydromodifications

Hydromodifications were identified on a segment by segment basis so that habitat impacts could be quantified by type and location in the watershed. There were two primary sources for hydromodification information. First, structures such as dikes, levees, bank revetments, road crossings, gravel mining sites, etc., were identified, measured, and associated with segments using USGS 7.5” topographic maps and aerial photographs. In some cases, hydromodifications identified on aerial photographs were verified in the field. Second, Washington State’s Department of Fish and Wildlife maintains a database tracking hydraulic projects around the state. This database was

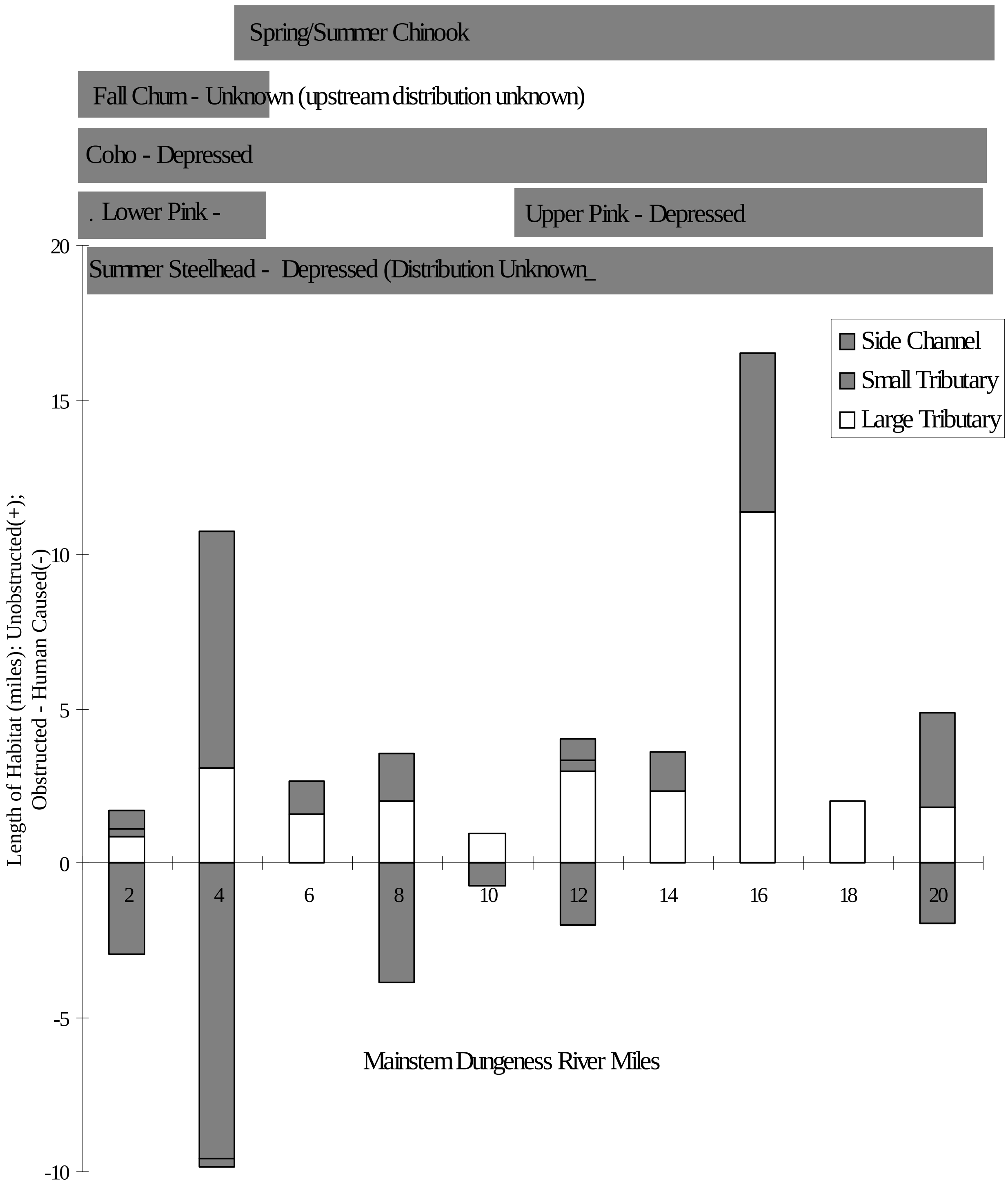

Figure 4. Dungeness River - Summary of Habitat and SASSI stock spawning distributions.

used to identify projects for further aerial photo analysis.

For the Dungeness River, mainstem and small tributary habitat was classified as either hydromodified or non-hydromodified. For mainstem habitat, if the channel showed sign of active or recent gravel mining, or if the channel was diked or the bank armored, the channel section was considered hydromodified. If none of these activities or structures were visible, or recorded by WDFW, the channel section was considered non-hydromodified. For tributary habitat, if the channel showed clear sign of ditching, channelizing, or bank armoring, the channel section was considered hydromodified. If the channel showed no clear signs of any of these impacts or structures, the channel section was considered non-hydromodified.

These criteria alone probably do not capture the true extent of hydromodifications. Orsborn and Ralph (1994) showed that channel constrictions created by bridges on the lower river are changing hydraulic conditions and degrading habitat, upstream and downstream of the constriction points. Furthermore, the large number of culverts directly affect a significant length of small tributary habitat. Also, a considerable amount of in-channel work has been conducted by the U.S. Forest Service in Gold Creek in failed attempts to stabilize banks associated with mass wasting (Golder Associates 1993). Many of these revetments have since been removed intentionally, or by failure. None of these alterations were accounted for in this analysis, and results should be considered conservative.

A total of 6.6 miles of the lower 10 miles of mainstem habitat was identified as hydromodified (Figure 5). This part of the river is considered important spawning habitat for three wild salmon stocks, lower pink, chinook, and chum. Two of these, lower pink and chinook, are considered critical (WDFW et al. 1994). A total of 14.3 miles of small tributary habitat was identified as hydromodified. Hydromodified habitat in small tributaries was concentrated among those joining the mainstem below river mile 5. Approximately 55 percent of the small tributary habitat and 66% of large tributary habitat below river mile 10 is hydromodified.

Results by stock

Spring/Summer Chinook

Background

Dungeness chinook was classified in 1992 as critical based on chronically low escapements (WDFW et al. 1994. Total escapement has ranged between 43 and 335 fish during the period 1986 to 1994. A captive broodstock program was initiated in recent years to maintain the viability of the stock while habitat and harvest issues could be addressed (Smith and Wampler 1995).

Dungeness spring/summer chinook are believed to be a single stock of native origin, however, there have been six releases of non-native chinook salmon into the Dungeness River since 1966. The effect of non-native releases on the integrity of the native stock has not been fully assessed, however, some have suggested that current run and spawn timing more closely resemble behavior characteristic of summer/fall stocks from which non-native introductions derive (McHenry et al. 1996). However, Smith and Sele (1995) recently found no discernible difference in run timing of Dungeness spring/summer chinook between the periods 1930 to 1981 and 1986 to 1991.

Synopsis

SASSI Status: Critical
Trend: Spawning escapements are chronically low with no discernible trend.
Timing: Spawning from August through September (WDFW et al. 1994).
Historical Distribution: Spawning occurs on the mainstem Dungeness River to rivermile 19, Gray Wolf River to rivermile 5, and associated side channel, and large tributary habitats (WDFW et al. 1994).
Lost Habitat: Not identified.
Obstructed Habitat: Approximately 1 mile, or 31 % of side channel habitat is obstructed by dikes. About 20 miles, or 51%, of small tributary habitat lie above culverts and have the

potential to obstruct juvenile access.

Hydromodifications: Approximately 6.6 miles, or 66 %, of mainstem habitat in the lower 10 miles of the river is hydromodified. Hydromodifications in the lower mainstem affect adult migration, spawning, incubation, and rearing. No mainstem hydromodifications were identified in the upper Dungeness or Gray Wolf Rivers, however, migration and rearing of upper river spawning populations are affected by hydromodifications in the lower river.

Other Impacts:

Sediment Aggradation

Sediment aggradation in the lower Dungeness River has reduced and degraded habitats important to every fresh water phase of the Dungeness spring/summer chinook life history (Reed and Bishop 1996). Streambed aggradation has so affected channel geometry that instream flow incremental studies (IFIM), targeted for chinook, have yielded instream flow recommendations that far exceed expected flows based on the long term USGS flow records. The impacts of aggradation are exacerbated by diking and irrigation withdrawal. Diking and other channel constrictions cut off the floodplain for storage of sediments; straighten, shorten, and steepen the channel by interrupting the natural meander pattern; and concentrate the energy of peak flows within the armored banks. An unstable (highly mobile) streambed and high energy flows increase the risk that redds will scour or be buried by gravel. The aggraded channel, particularly on the diked reaches, is characterized by long, shallow, sometimes braided, riffle type reaches with few pools. These conditions make upstream migration difficult for adult chinook, especially during low flow conditions.

Irrigation withdrawal and ditches

The area of available habitat to spawning and rearing chinook is further reduced by irrigation withdrawals from the lower Dungeness River. At low flow periods, irrigation withdrawals amount to as much as 40% to 60% of natural flow (WDFW et al. 1994). Juvenile chinook are at some risk of entrainment in irrigation ditches, even when fish screens are well maintained (Hiss 1987). Irrigation ditches of the Dungeness River

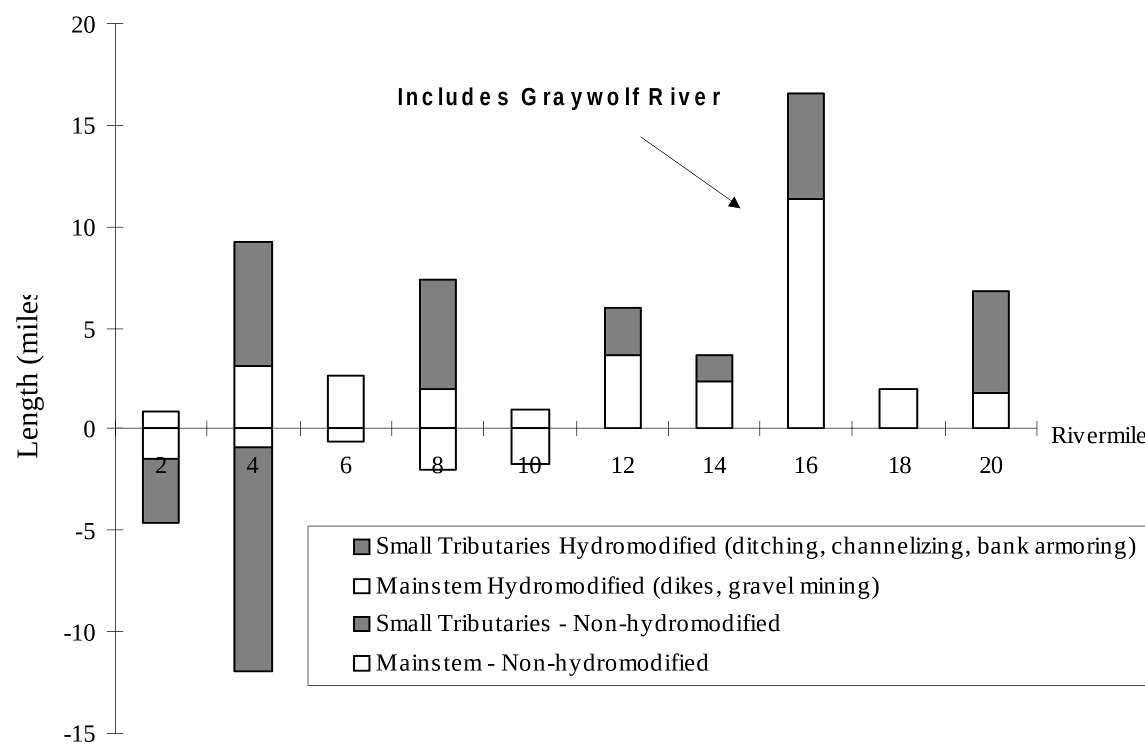

Figure 5. Dungeness River - Summary of Hydromodified Habitat.

are not suitable habitat for juvenile salmonids for several reasons. First, the ditches are periodically dried. Second, water temperatures are high because there is little or no shading of the ditches. Finally, ditches receive agricultural runoff consisting of manure, fertilizers, pesticides, and herbicides (Hiss 1987, see also section water quality).

Stream Temperature
Maximum stream temperatures in the lowest reaches of the mainstem Dungeness exceed the preferred range for spawning during August and September. Loss of a functional riparian area, water withdrawal, and streambed aggradation in the lower 10 river miles all contribute to the elevated temperatures in the lower river.

Fall Chum
Background

Data for Dungeness fall chum escapement are of poor quality. The aggregate escapement goal for all Strait of Juan de Fuca streams has been exceeded in only five of the last 25 years (McHenry et al. 1996). Recent stock assessments have classified Dungeness fall chum as unknown (WDFW et al. 1994) and threatened (McHenry et al. 1996). The stock is considered native because there have been no documented releases of non-native chum salmon to the Dungeness River (WDFW et al. 1994).

It is believed that fall chum currently utilize the lower ten miles of mainstem and associated side channels for spawning. McHenry et al. (1996) suggest that as many as three other chum stocks may have once utilized different areas of the watershed.

Synopsis
Status: Unknown
Trend: Unknown, data is of poor quality.
Timing: River entry occurs as early as late October, spawning from November through December (WDFW et al. 1994).
Historical Distribution: Unknown. Fall chum currently use the lower mainstem and associated side-channels for spawning.
Lost Habitat: Not identified.
Obstructed Habitat: Two side channels on the lower mainstem account for approximately 1 mile (or 31% of all side channel habitat) of dike-obstructed habitat.
Hydromodifications: Approximately 6.6 miles, or 66 %, of mainstem habitat in the lower 10 miles of the river is hydromodified. Hydromodifications affect adult migration, spawning, and incubation.
Other Impacts: Unstable streambed conditions owing to sediment aggradation and channel constrictions on the lower river have the potential during peak flows to scour or bury redds constructed by spawning chum salmon. See “other impacts” for spring/summer chinook.

Coho
Background

Dungeness coho are managed for hatchery production. Small tributaries, including Hurd and Canyon Creeks, and the Gray Wolf River have received significant plants of non-native juvenile coho. Due to these considerable plants, Dungeness hatchery coho are considered a mixed origin stock. There is very little information concerning native, wild coho production in the Dungeness, or the impacts on this stock from decades of outplanting. WDF et al. (1993) characterized Dungeness coho as depressed due to short term severe decline.

Synopsis
SASSI Status: Depressed
Trend: Adult escapement estimates indicate short term severe decline.
Timing: River entry begins in October, spawning from November through early January (WDFW et al. 1994).
Historical Distribution: Mainstem Dungeness River to rivermile 19, Gray Wolf River to rivermile 5, associated side channels, large and small tributaries, and small independent tributaries to the Strait of Juan de Fuca.
Lost Habitat: Not identified**.**
Obstructed Habitat: Approximately 1 mile, or 31 % of side channel habitat is obstructed by dikes. 20 miles, or 51%, of small tributary habitat lies above culverts that have the potential to obstruct juvenile and adult access.
Hydromodifications: Approximately 6.6 miles, or

66 %, of mainstem habitat in the lower 10 miles of the river is hydromodified. Hydromodifications in the lower mainstem affect adult migration, and rearing. On diked reaches of the river juvenile coho have few areas of refuge during peak, high velocity flows. Lack of holding pools in many parts of the aggraded and hydromodified channel make adult migration problematic. No mainstem hydromodifications were identified in the upper Dungeness or Gray Wolf Rivers, however, migration and rearing of upper river spawning populations are affected by hydromodifications in the lower river. Approximately 14 miles of small tributary habitat was identified as hydromodified (ditched, armored). Hydromodified habitat in small tributaries was concentrated among those joining the mainstem below river mile 5. Approximately 55 percent of the small tributary habitat that joins the mainstem below river mile 10 is hydromodified. Hydromodifications in small tributaries affect all fresh water phases of the Dungeness Coho's life history.

Other Impacts

Irrigation withdrawals
Irrigation withdrawals, particularly during low flow periods of the year, exacerbate the effects of streambed aggradation and hydromodifications described above.

Irrigation ditches
Juvenile coho are at some risk of entrainment in irrigation ditches, even when fish screens are well maintained (Hiss 1987). Irrigation ditches of the Dungeness River are not suitable habitat for juvenile salmonids. First, the ditches are periodically dried. Second, water temperatures are high because there is little or no shading of the ditches. Finally, ditches receive agricultural runoff consisting of manure, fertilizers, pesticides, and herbicides (Hiss 1987).

Upper Pink
Background

There are two distinct pink stocks in the Dungeness River: upper Dungeness pink and lower Dungeness pink. The upper Dungeness pink is genetically distinguishable from all other Washington State pink stocks, including the lower Dungeness pink (WDFW et al. 1994). As the name suggests, they utilize upper portions of the watershed for spawning Adult upper Dungeness pink enter the river in July, still in "ocean-bright" condition, and complete spawning by the end of September. This is much earlier than is usual for all other pink salmon stocks in the region.

WDFW et al. (1994) classified the status of upper Dungeness pink as depressed due to chronically low escapement. Total escapement has ranged between 55000 and 1800 during the period 1967 to 1991. The population declined dramatically following devastating floods in 1979 which destroyed incubating eggs (Lampsakis, personal communication, Point No Point Treaty Council). Upper Dungeness pink have shown some signs of recovery since 1981, whereas lower pink escapements have remained low (Figure 5). The degraded, modified habitat conditions of lower river habitat used by lower Dungeness pink may account for its continued decline. (Figure 6).

Synopsis

SASSI Status: Depressed
Trend: Chronically low adult escapement since 1979 but with some signs of recovery.
Timing: River entry occurs in July, spawning from August through September (WDFW et al. 1994). Pink smolts (both upper and lower stocks) begin arriving in Dungeness Bay in early April and utilize the estuary through the month of May (Hiss, 1994).
Historical Distribution: Spawning occurs in the upper mainstem Dungeness from rivermile 10 to rivermile 19 and associated small tributaries (e.g. Gold Creek), and in the Gray Wolf, and associated small tributaries, from the confluence with the Dungeness to the junction with Cameron and Grand Creeks (WDFW et al. 1994).
Lost Habitat: Not identified.
Obstructed Habitat: Approximately 2 miles, or 10 %, of potential upper pink habitat in small tributaries lies above culverts that may obstruct adult access.

Hydromodifications: Lower mainstem hydromodifications described above for spring/summer chinook impact upper Dungeness pink to the extent that they affect adult migration. In particular, streambed aggradation within channels confined by dikes, armored banks, or bridges degrade migratory habitat. Adult migration during low flow conditions through the aggraded lower river is problematic due to few and poor quality holding pools and the generally braided condition of the channel between river miles 4 and 8.

Other Impacts: Irrigation withdrawals during low flow conditions exacerbate upstream migration problems. Hatchery production of coho salmon could result in increased pink salmon predation.

Lower Pink
Background

Lower Dungeness pink enter the river in mid-September and complete spawning by late October (WDFW et al. 1994. As previously mentioned, the lower pink stock suffered a severe decline in abundance following the devastating flood in 1979. Escapement since then has been as low as 138 fish (see Figure 5). Lower Dungeness pink have been classified as critical (WDFW et al. 1994 McHenry et al. 1996). Nehlsen et al. (1991) rated Dungeness pink (both stocks) at moderate risk of extinction.

Synopsis

Status: Critical
Trend: Downward trend since late 1960s. Precipitous decline following 1979 floods that destroyed redds. Chronically low adult escapement since 1981 with no sign of recovery.
Timing: River entry occurs in September, spawning from September through October (WDFW et al. 1994).
Historical Distribution: Mainstem Dungeness River to approximately rivermile 6 and associated small tributaries. Pink smolts (both upper and lower river stocks) begin arriving in Dungeness Bay in early April and utilize the estuary through the month of May (Hiss, 1994).
Lost Habitat: Not identified.
Obstructed Habitat: 14 miles, or 36%, of potential pink salmon habitat in small tributaries lies above culverts that may obstruct adult access.
Hydromodifications: Approximately 3 miles, or 50%.
Other Impacts: Unstable streambed conditions owing to sediment aggradation and channel constrictions on the lower river have the potential during peak flows to scour and fill redds constructed by spawning pink salmon. See “other impacts” for spring/summer chinook. Hatchery production of coho salmon could result in increased pink salmon predation.

Summer Steelhead
Background

Very little information exists concerning Dungeness summer steelhead. Distribution of spawning is unknown but believed to be concentrated in upper reaches of the river. Entry of adults is unknown but believed to occur from May through October. Spawn timing is likewise unknown but believed to occur from February through April. Stock origin and production type were not resolved by SASSI (WDFW et al. 1994). Spawning escapement is not monitored, but sport catches of Dungeness summer steelhead have been low in recent years ranging between 8 and 47 during the years 1986-1991. WDFW et al. (1994) described the status of summer steelhead as depressed due to short term severe decline.

Synopsis

Status: Depressed
Trend: Only data available are sport harvest records which indicate recent decline.
Timing: Exact spawn timing is unknown but thought to occur from February through April (WDFW et al. 1994).
Historical Distribution: Spawning distribution is unknown, but is assumed to occur in the upper reaches of the Dungeness, Gray Wolf, and their tributaries (WDFW et al. 1994).
Lost Habitat: Not identified.
Obstructed Habitat: Approximately 1 mile, or 31% of side channel habitat is obstructed by

dikes. About 20 miles, or 51%, of small tributary habitat lie above culverts that have potential to obstruct juvenile and adult access. A total of 57 culverts were identified in the potential range of summer steelhead.

Hydromodifications: Approximately 7 miles, or 70%, of mainstem habitat in the lower 10 miles of the river is hydromodified.

Hydromodifications in the lower mainstem affect adult migration, and rearing. On diked reaches of the river juvenile steelhead have few areas of refuge during peak, high velocity flows. Burrowing into gravels during peak flows is probably not a useful strategy since the streambed is unstable over much of the lower 10 miles of mainstem. No mainstem hydromodifications were identified in the upper Dungeness or Gray Wolf Rivers, however, migration and rearing of upper river spawning populations are affected by hydromodifications in the lower river. Approximately 14 miles of small tributary habitat was identified as hydromodified (ditched, armored). Hydromodified habitat in small tributaries was concentrated among those joining the mainstem below river mile 5. Approximately 55 percent of the small tributary habitat that joins the mainstem below river mile 10 is hydromodified.

Winter Steelhead Background

Spawning escapements for Dungeness winter steelhead have ranged between 176 and 438 during the years 1988 to 1992. WDFW et al. (1994) described the status of winter steelhead as depressed due to chronically low escapement. Adult winter steelhead are believed to enter the river from December through May. Spawning occurs from mid-February through early June and is located on the mainstem to rivermile 20, the Gray Wolf River to the confluence with Grand and Cameron Creeks, and associated tributaries. There have been significant plants of native and non-native steelhead stocks to the Dungeness (McHenry et al. 1996).

Synopsis

Status: Depressed

Trend: Adult escapement is chronically low with no discernible trend. Adult escapement has ranged between 176 and 438 during the period from 1988 to 1992 (WDFW et al. 1994).

Timing: Run timing is believed to occur from

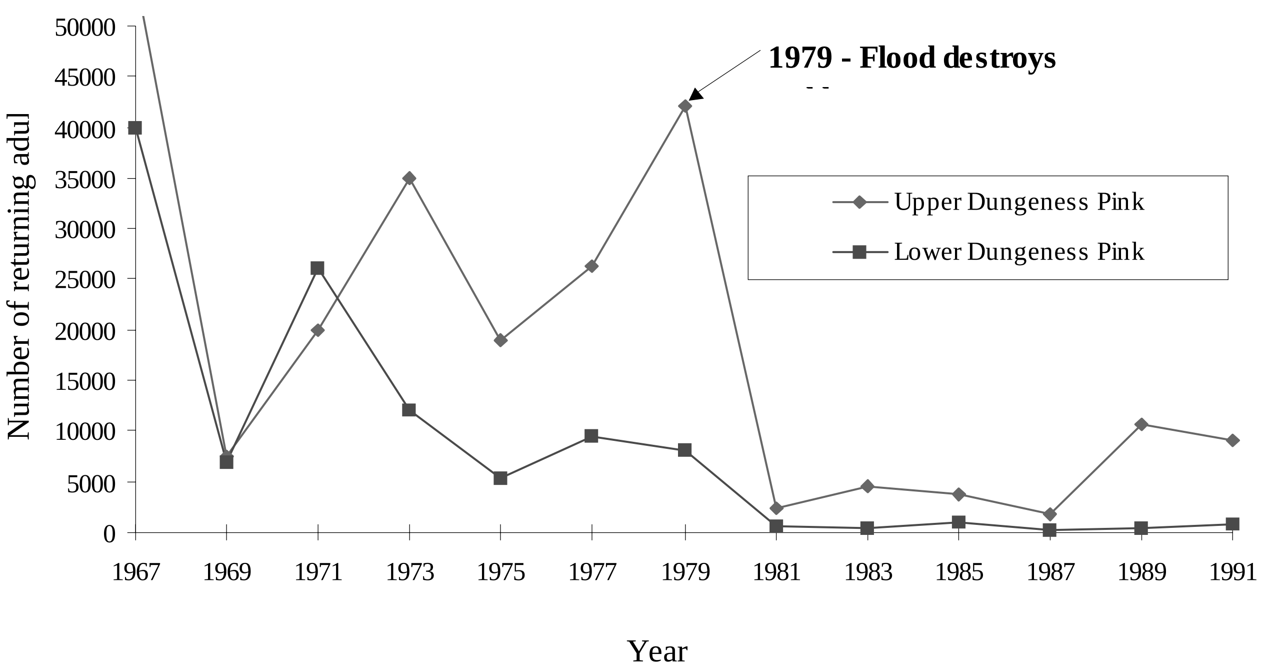

Figure 6. Dungeness River adult Pink salmon escapement.

December through May. Spawning occurs from mid February through early April (WDFW et al. 1994).

Historical Distribution: Winter steelhead utilize the mainstem Dungeness to rivermile 19, the Gray Wolf to the junction with Cameron and Grand Creeks, and associated tributaries.

Lost Habitat: Not identified.

Obstructed Habitat: Same as for Dungeness summer steelhead.

Hydromodifications: Same as for Dungeness summer steelhead.

Discussion

The Dungeness River is one of the most studied watershed systems on the Olympic Peninsula. Interest in the watershed is explained by its value to timber, agriculture, fish and wildlife, recreation, and the ecological importance and inherent beauty of its remaining wild areas located within the Olympic National Park.

Another reason for the research interest is that the Dungeness River, particularly from a salmon habitat perspective, provides many examples, common to the region, of how to mismanage a watershed. The integrated effect of logging activities in specific locations of the upper watershed and decades of agricultural, commercial, and residential activities in the lower watershed is an aquatic environment downstream of river mile 11 that threatens the long term viability of at least three wild anadromous salmon stocks.

Lower Mainstem Dungeness River Impacts
Dikes, roads, ditches, and excessive withdrawal of water for irrigation have blocked, obstructed, and degraded miles of productive low gradient habitats used by anadromous salmon and steelhead.

Forest management activities, particularly road building in geologically sensitive areas of the watershed have increased bedload sediment yields. These sediments have, in recent decades, deposited in the lower river causing generally aggraded conditions. Aggradation is exacerbated by dikes and other modifications that shorten the channel and cut off the floodplain, a natural area of sediment storage. Pool quantity and quality, important both for migrating adult salmon and rearing juvenile salmon, have suffered in the lower, aggraded mainstem (Orsborn and Ralph 1994). Aggradation has so affected habitat conditions that ideal flows developed by IFIM studies far exceed historical flows for the river (Reed and Bishop 1996).

A non-functional floodplain behind the dikes and bridge constrictions has other implications. Most importantly, the energy of peak flows is now concentrated within the armored, constricting dikes resulting in bed instability from increased shear stress. This is a perilous situation for incubating eggs, pre-emergent fry, and to juvenile fish that seek out the gravel stream bed for refuge from high velocity flows. Also, juvenile fish that would normally use low velocity floodplain areas and side channels are exposed to the periodically high velocity flows of the main channel and an increased risk of being forced prematurely into Dungeness Bay.

Landowners have responded to the risks posed by the unstable, aggraded river bed by mining gravel in many areas of the lower river. Gravel is mined both for its commercial value and to protect private property by lowering bed elevations so that the channel can convey lower frequency peak flows. The tailouts of these pool-like “gravel-traps”, as they are locally known, create hydraulic conditions that are apparently attractive redd sites for wild chinook and pink salmon, both critical stocks (Reed, personal communication, Jamestown S’Klallam Tribe 1996). Areas of the channel near gravel mining operations are particularly unstable and subject to fill and scour (Orsborn and Ralph 1994). Spawning salmon may be choosing these areas for spawning due to the lack of other suitable

Table 7. Numbers and locations of culverts and stream crossings within anadromous reaches on small tributaries in the Lower Dungeness.

Stream name	WRIA stream number	Rivermile location	Number of culverts
Meadowbrook Creek	180020	0.0 - 0.5	4
Mattrioti Creek	180021	0.0 - 1.8	8
Mattrioti Creek	180021	1.8 - 4.2	5
Mattrioti Creek	180021	4.2 - 5.6	5
Mattrioti Creek	180021	5.6 - 7,8	5
Unnamed	180022	0.0 - 2.1	2
Unnamed	180023	0.0 - 1.0	1
Unnamed	180024	0.0 - 2.0	5
Unnamed	tributary to Mattrioti Creek	0.0 - 2.0	3
Hurd Creek	180028	0.0 - 3.0	4
Bear Creek	180030	0.0 - 3.0	5

locations within the channel.

Lower mainstem habitat conditions described above affect all seven anadromous salmon stocks that use the Dungeness watershed, but are particularly pernicious to the three stocks, chinook, lower pink, and chum, that depend on the lower river for spawning.

Small Tributary Impacts

Impacts to small tributary habitats, as explained above, are concentrated in the lower watershed and are commonly associated with agricultural and residential land uses. As discussed previously, most (approximately 55%) small tributaries in the lower watershed have been channelized. In an assessment of a small, nearby watershed, Bahls and Rubin (1996) documented the impacts of channelization on salmon habitat. These impacts are probably similarly affecting small tributary habitat in the lower Dungeness watershed:

*Direct loss of habitat from channel straitening; loss of channel meander pattern (sinuosity).
*Loss of habitat complexity. Dramatic alteration of pool:riffle pattern with general loss of pools.
*Direct loss of rearing ponds and wetlands, notably those created and maintained by beaver.
*Loss of large woody debris.
*Degradation of riparian areas: few trees for shade and LWD recruitment, dominance of invasive exotics such as reed canary grass.
*Elevated temperatures and depressed dissolved oxygen from poor riparian function.
*Fine sediment deposition in channel.

These impacts may be exacerbated by bank erosion, degraded water quality from pollution originating in agricultural and residential areas, and modifications in watershed hydrology that accompany rural and residential development (Booth 1991, Lucchetti and Fuerstenberg 1993). The implications of these impacts are limitations on coho spawning and rearing, steelhead spawning and rearing, and chinook rearing.

In addition, dozens of culverts are potentially obstructing juvenile and adult access. There are 34 culverts or stream crossings on anadromous reaches of Matriotti Creek and its tributaries alone. The status (obstructing or not obstructing) of the vast majority of culverts in the basin is unknown.

Restoration and protection strategies

Lower Dungeness Mainstem

The Dungeness Habitat Work Group (DHWG), established in 1994 on the recommendation of The DQ Plan[1], has developed habitat restoration recommendations for the Dungeness River which are now in draft form. DHWG has so far focused on conditions in the lower mainstem Dungeness and associated side channels and habitats important to chinook and lower pink, the two critical salmon stocks in the system. The DHWG restoration plan is a departure from the engineering control mentality that has dominated management decisions on the lower river for decades. The draft restoration plan instead advocates returning natural function to the lower river and its historic floodplain with the ultimate goal of stabilizing mainstem habitats while simultaneously addressing the long term risks to private property from floods and channel sediment processes. It is hoped that this approach will win the support of both private property owners, water users, and fishery user groups (tribal, commercial, and sport fishers).

The principal elements of the DHWG restoration plan for the lower Dungeness are summarized as follows (DHWG 1996):

1. Reestablish functional floodplain in the lower 2.6 miles through dike management and constriction abatement.
2. Abate man-made constrictions upstream of the US Corps of Engineers' dike (upstream of rivermile 2.6).
3. Create numerous stable log jams.
4. Manage gravel and fine sediment.
5. Side channel construction/protection.
6. Restore suitable riparian vegetation and riparian-adjacent upland vegetation.
7. Conserve instream flows.

Specific project recommendations are ambitious. They include significant dike setbacks, side channel construction, log jam and large woody debris placement, and revegetation of riparian areas.

Small Tributaries

Habitat impacts in small tributaries to the Dungeness are primarily associated with channelization and culverts. As much as 55% of small tributary habitat in the lower Dungeness watershed has been channelized, and there are dozens of culverts located on public and private roads that may affect salmon and steelhead access.

1. Instream assessments should be per formed so that habitat conditions and their current and potential importance to salmon stocks is more fully understood.
2. Further characterization of the historic condition of small tributary habitats should be undertaken to assess the historical importance of off-channel ponds and wetland areas to salmon and steelhead lifehistories in small tributaries of the Dungeness watershed.
3. A field inventory and assessment of culverts should be conducted. Table 7 lists the general location of 47 culverts on 8 tributaries in the lower watershed that may affect anadromous passage. Correcting blocking culverts and other man-made obstructions is perhaps the easiest method of restoring habitat.
4. Wherever appropriate, stream banks and riparian vegetation should be fenced to protect them from livestock.
5. Riparian areas should be planted with conifer tree species to provide shade, protect banks, and supply future large woody debris.
6. Explore feasibility of restoring meandering channels and off-channel ponds and wetland areas. This will depend on the results of the historic characterization of off-channel habitats, (2 above).

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[1] The 1990 Chelan Agreement established a framework for regional water management planning with the objective of balancing the consumptive demands on water resources with the needs of fish and wildlife resources. The Dungeness-Quilcene Water Resources Planning Project was one of two pilot areas chosen to test process defined in the Chelan Agreement. The Dungeness-Quilcene Water Resources Management Plan, "DQ Plan", was published in 1994.

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